Proposal

1. All of the work proposed in 3.2.B will be accomplished under the EROS contract and the ASSP.

2. There seems little to be gained by carrying out the work in 3.2.C.

3. Aspect Δs, scale differences and resolution inputs will all be investigated under the two existing contracts.

4. It appears that the entire output of this study would be taken from the EROS and ASSP. We should get all the answers we need on the <u>optical</u> approach to transformation, correlation and integration from these two contracts.

5. Is an electronic system feasible as originally stated? Does the new proposal mean that the electronic system is not feasible.

6. Phase II Submit a proposal to follow the electronic approach of a MII Printer.
Study should define the limitations of MII Printer in terms of MTF, S/N, and BW with variables such as resolution, attitude distortion, focal length, shadow, relief, focal length, lens distortion, etc.

7. Start thinking of 150 - 200 line/mm input.

8. Make proposal comprehensive & factual

9. What are the limitations of MTF and S/N which seem much more serious than Bandwidth.

10. We are interested in the electronic approach due to the great versatility it seems to possess and it is this

some versatility that we need for our materials. We never did get much on this from the study.
What net gain can be achieved through the system and what is the amount or magnitude of the gain.

11. The original contract was to:
a. Define the net gain potential
The time required
The degree of flexibility of the system that could be built

12. Limitation on number of inputs

13. The proposal was [illegible] factual.
Just what will [illegible] [illegible] [illegible] [illegible]?

PROPOSED CHANGE OF SCOPE

For

MULTIPLE IMAGE INTEGRATION STUDY

August 1966

STAT

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MULTIPLE IMAGE INTEGRATION STUDY

1. Introduction

The first phase of this study was concerned with an analysis of the problems of image integration, and the initial design for a three-input image integration viewer/printer that would enable a practical evaluation of the benefits to be obtained from the combination of several images of the same object.

The hardware approach was based on the use of electronic imaging and video processing, using the ARES image correlation techniques. Relative geometrical distortion between the inputs was to be cleared by changing the shape of the cathode ray tube scanning rasters. Because of the requirement for high resolution, a slow scan print-out onto film was to be used; direct viewing of the integrated image at high resolution was not possible. The resolution capability of the proposed image integration viewer at 12X magnification was estimated to be similar to that of a high quality photographic enlarger with a limiting resolution in the region of 80 - 100 lines/mm.

For the purpose of image integration, an electronic imaging system has the advantages that (1) high-order image distortions, even those due to stereo relief, can ultimately be corrected, (2) a considerable degree of video processing can be introduced. This is especially necessary with material taken at different times of day or in different seasons of the year, and may be desirable with multi-sensor material.

The main limitation of an electronic system is its restricted bandwidth which limits the number of resolution elements that can be displayed per second.

The only way of obtaining a high resolution direct viewing capability is by the use of an optical system. Since the interim report on the Multiple Image Integration Viewer/Printer was issued (Dec. 1965) the feasibility of using an optical system to automatically correct image distortion has been established. This method will presently correct zero and first-order distortion, and offers direct viewing of images with the ability to see detail at 150 - 200 lines/mm. These advantages may outweigh the lack of video processing capability. The problem of high order distortion due to different aspect angles can be overcome very neatly in an optical system by taking the inputs two at a time and using them as stereo pairs. All images would first be normalized or reduced to the same scale, and then selected in pairs as required by the photointerpreter. Direct superimposition of the images is also possible, and experiments with various change detection techniques could be made. A further advantage of an optical viewing system is that color material can be used.

An automatic registration optical viewer is consequently a very powerful tool with which to conduct an intensive study of multiple image integration techniques.

2. EROS Tests

To provide some initial data on the feasibility of an optical system for multiple image integration, some tests were conducted on the EROS viewer. The material used was high-resolution, black and white material comprising three coverages of the same area.

In order to see all detail on the input material, the maximum EROS magnification of 24X had to be employed. At this magnification, the precision of the X-Y film transport is not sufficient for critical viewing. To provide optimum viewing, a further increase in magnification to 50X or 100X would be required. This would also improve correlation efficiency, because at present much detail is beyond the resolution of the correlation system.

Within the limitations imposed by the film transport and lack of magnification, the results were very encouraging. Good correlation was obtained between photographs taken at different times, and stereo viewing of this material appears to be feasible. The conclusions to be drawn from these initial tests are that

(1) An optical viewing system with image transformations is suitable for image integration.

(2) A magnification of 50X to 100X is required for integration of high resolution photography.

(3) A highly precise film positioning system is necessary.

(4) An image correlator sensitive to high spatial frequencies is desirable.

The EROS equipment in its present form would not be suitable for this purpose without considerable modification.

3. Proposed Program

In order to evaluate the potential of multiple image integration, it is proposed that (1) a breadboard optical system to accept up to three inputs be constructed, (2) an extensive study program covering many aspects of multiple image integration be conducted. The breadboard equipment would be intended solely to support the study program, on which the major effort would be expended.

3.1 Breadboard Equipment

3.1.1 Requirements

In order to properly evaluate the various techniques which may be applied to image integration, the following general equipment requirements are established.

(a) Direct optical viewing, with a resolution of 150 lines/mm or better.

(b) Automatic correction of parallax, scale, rotation and anamorphic magnification.

(c) Superimposition of up to three images which have been optically normalized.

(d) Stereo viewing of any two combinations of the three images.

In addition, the breadboard equipment should be flexible in design so that the incorporation of optical or spatial filtering could be investigated.

3.1.2 Proposed Equipment

In order to permit accurate and efficient image integration, means must be provided to transform the images, optically, in order to provide registration. Zero and first order corrections (parallax, scale, rotation and anamorphic magnification) will be applied using methods similar to those employed in the EROS equipment described previously.

The error signals used to drive the optical and mechanical elements will be derived by scanning each photograph with a vidicon tube, correlating the resulting video signals, and analyzing the relative distortion into its basic components.

The use of vidicons to produce video signals for correlation considerably simplifies the optical design compared to the present EROS system which uses a CRT scanner, and optical duplexing.

A block diagram of the breadboard equipment proposed is shown in Fig. 1. The optical system is based on that of the EROS viewer, with higher magnification capability of 25X to 100X. The first (objective) lens will have a magnification of 10X, the zoom system will be variable from .25X to 1X, and 10X eyepieces will normally be used.

Photograph B can be considered the reference, with photographs A and C capable of being correlated and transformed to match B. Rotation and anamorphic correction are not required in the B leg, resulting in considerable simplification of the optics. Individual light sources are used for the photographs and neutral density filters may be placed in each optical path to provide similar illumination levels. Only one correlation system will be required, as each of the A and C inputs are sequentially corrected to match B. Stereo viewing of any selected pair, AB, AC or BC can be carried out or superposition of any two, or all three photographs can be viewed, by suitable switching of mirrors.

Provision will be made for hard copy print-out of the superimposed image. This will consist of the image normally viewed in the eyepiece, at a magnification of 2.5X to 10X relative to the input film.

In order to simplify the breadboard equipment, it is proposed that chips up to 2 x 2 inches be used with the film chip mounted on a glass platen which is capable of being transported in X and Y by a servo driven stage.

Previous experience with similar correlation equipment indicates that registration of images to an accuracy of about 0.1% of the width scanned can be achieved. Thus, in order not to degrade the 150 lines/mm resolution capability imposed, the area examined at maximum magnification should be no more than 2 mm square for direct integration of imagery. Stereo viewing would allow somewhat more tolerance on the field of view. A 4 - 1 zoom range should be adequate to allow evaluation of image integration techniques.

Modulation transfer curves for the optical integration viewer are shown in Figure 2. Resolution measurements made on the EROS viewer have shown that the resolution of the image transformation system alone (zoom lens, rotation mirrors and two anamorphic lenses) is about 60 lines/mm. With the objective lens of 2.5X presently employed, overall limiting resolution has been measured at 160 lines/mm, which is approximately 2.5 x 60 lines/mm. This shows that the image transformation system effectively limits overall resolution when low power objectives of up to 2.5X are used.

With a high power objective of 10X magnification, the situation is quite different. In this case, the limiting resolution of the transformation system becomes 600 lines/mm referred to the input film, which is far above the resolution of the objective lens. Under this condition therefore, the overall resolution is determined largely by the objective lens.

Figure 2 shows the MTF of a typical high quality enlarging lens at 10X, together with the modulation curve of a typical aerial photograph on 3404 film. The resulting MTF of the visual image, as seen in the eyepieces is also shown. To determine the MTF of the hard copy, the characteristics of the copy film must be taken into account; a curve for type 8430 film is shown, together with the expected MTF of the recorded image.

It can be seen that in order to see ground detail recorded on the film at around 100 lines/mm, the optical system must have a limiting resolution of over 200 lines/mm.

3.2 Study Program

The study program will constitute the major part of the proposed work. The use of a high resolution optical system will enable the effects of multiple image integration to be investigated for any type or combination of input material. Because of the use of direct optical viewing, the results obtained and any new techniques developed will be directly applicable to a real photointerpretive operation in which speed and accuracy are vital.

The main areas to be studied will be as follows:

A. Integration of two and three photographic inputs with appropriate geometrical transformations into a single integrated output. Among the factors whose influence on the quality of the final image must be accounted for are:

(1) Aspect angles of the inputs

(2) Scale differences in original material

(3) Resolution of original material

The integration of black and white material with color photography will also be investigated.

B. Integration of photographic inputs two at a time, using stereo viewing. The factors to be investigated will be:

(1) What range of aspect angles can be accommodated by stereo viewing.

(2) How accurately must scale and geometry be matched.

(3) What difference in resolution can be accommodated between the two inputs.

(4) The effect of mixing black and white and color material.

C. Integration of multi-sensor inputs into a single output or a stereo pair. Because of the difference in appearance of imagery produced by different sensors, there is a considerable correlation problem with this material. Because IR and radar systems do not produce the same resolvable detail as an optical system, the additional information obtained through multi-sensor integration is largely in the form of cues which must be matched with recognizable objects on a visual photograph. Methods of achieving this aim, by direct superimposition or stereo viewing will be investigated. The possibility of color coding the multi-sensor inputs will be considered, as will the use of flicker techniques.

The material required to conduct this study will consist of photographic coverage of several different areas obtained by several missions at different times of the year.

Both panoramic and oblique material will be used with as wide a range of scale and aspect angle as possible. Both color and black and white coverage will be required. Multi coverage material comprising photographic, [redacted] of the same area will be necessary. The imagery produced by active radar systems is primarily composed of specular reflections and the detailed appearance of most objects varies with the orientation of the line of flight. To properly evaluate the integration of radar imagery with photographic imagery it is therefore necessary to have samples obtained on several different runs.

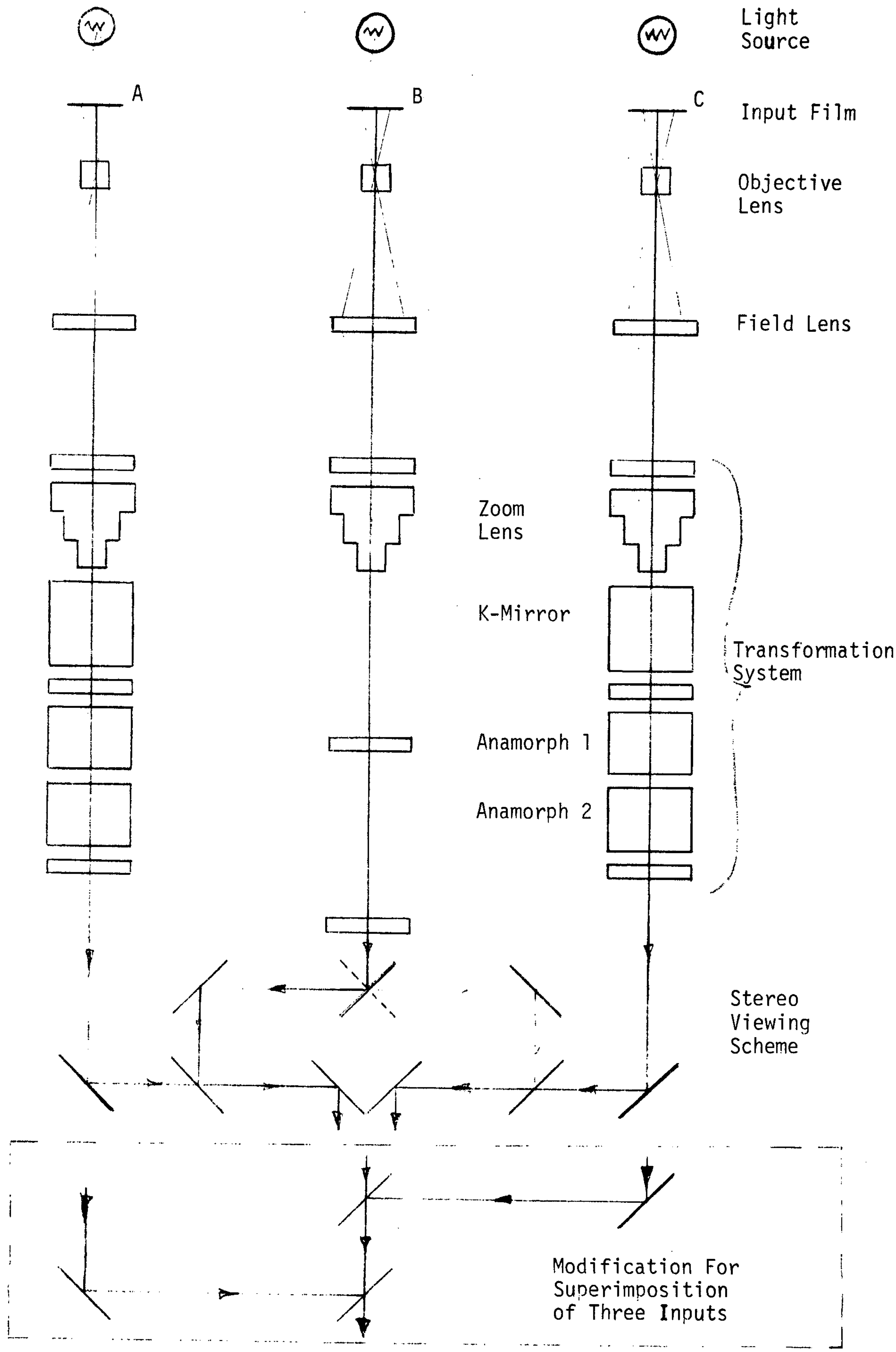

FIGURE 1 OPTICAL IMAGE INTEGRATOR

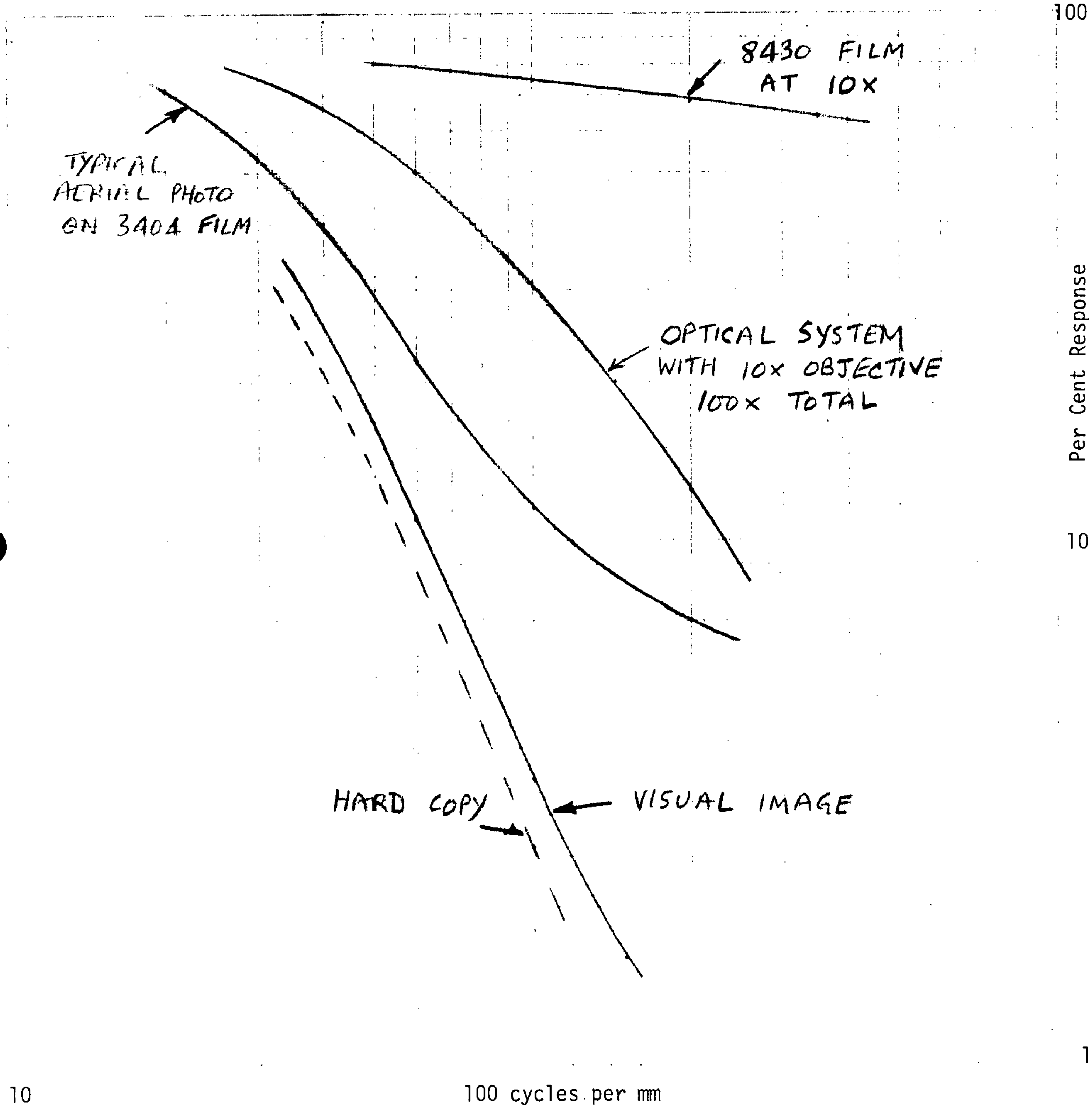

FIGURE 2 MODULATION TRANSFER FUNCTIONS